Mars Sample Return Conceptual Mission Overview

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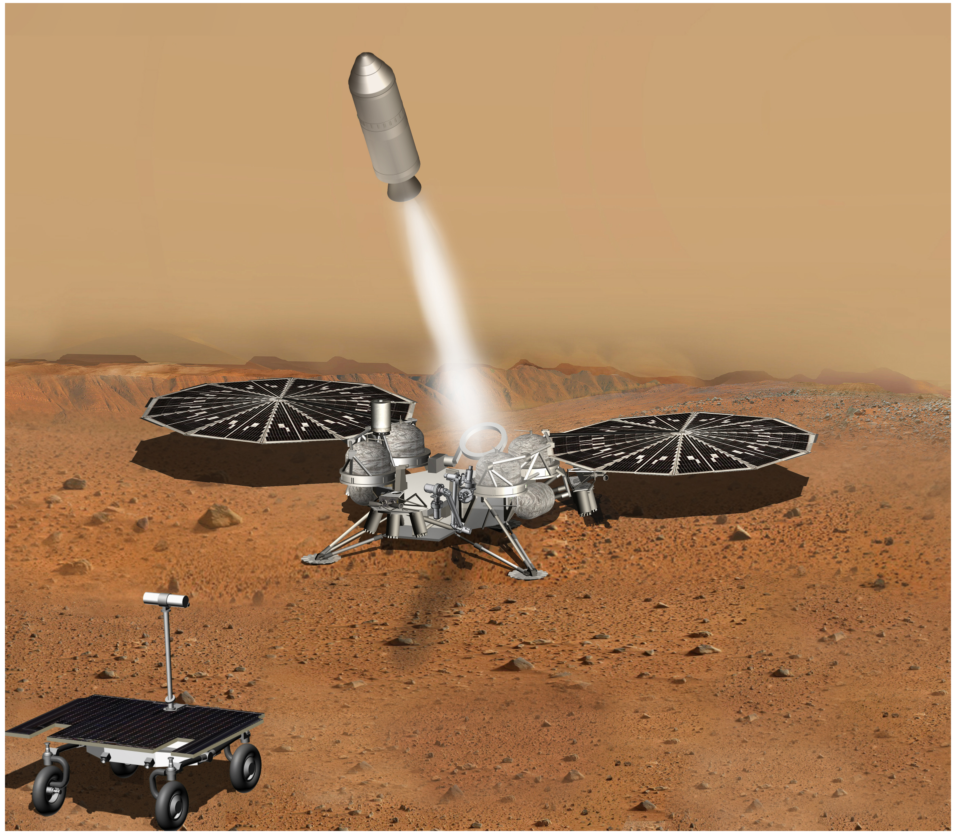
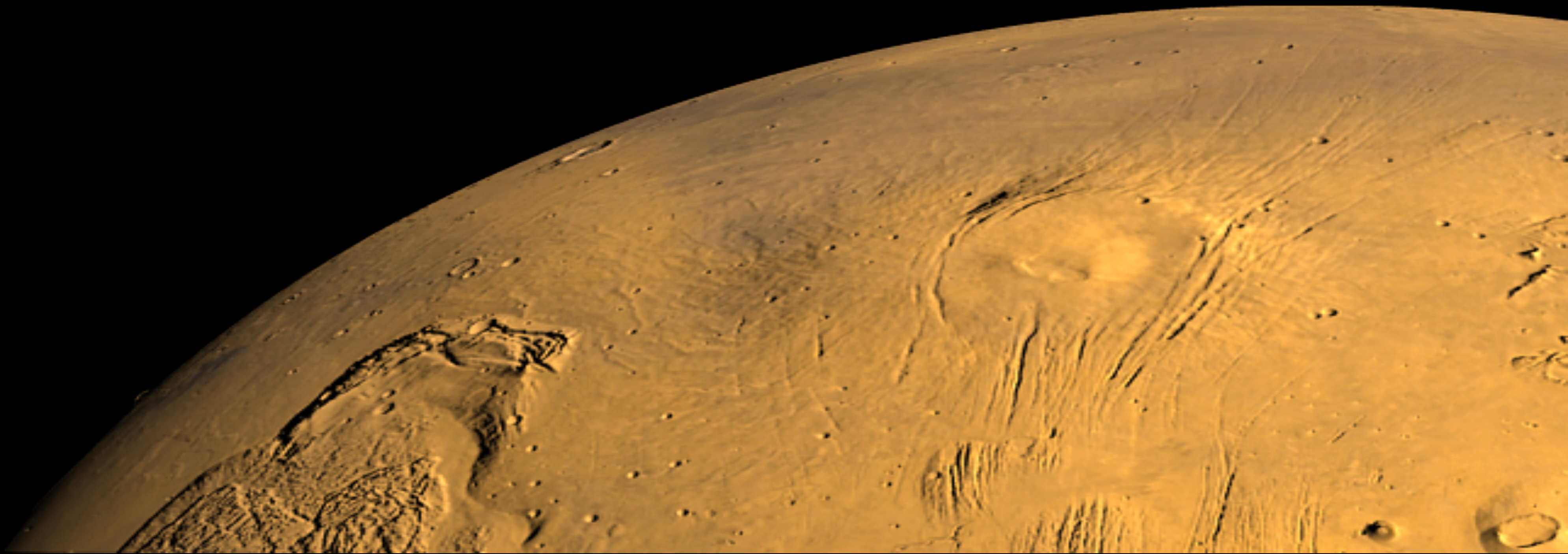
Agenda

- Mars Sample Return Campaign Discussion
  - Functional Objectives
  - MSR Architectural Elements
  - MSR Mission Scenario and Roles
  - Current Operations Timeline
  - Backward Planetary Protection
  - Key Trades and Systems Engineering
- MSR Element Concepts
  - Lander Concepts Under Study
  - Orbiting Sample Container Concept and Sample Transfer Arm
  - Mars Ascent Vehicle Concept
  - Sample Fetch Rover Concept
- Summary

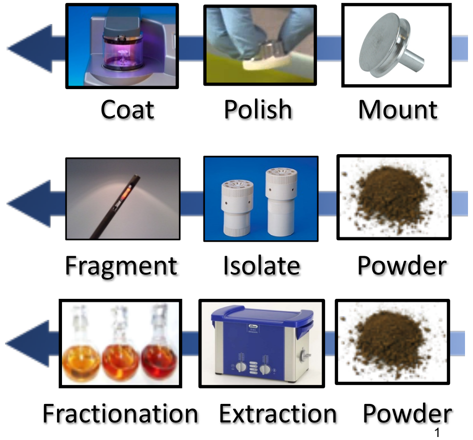


Mars Sample Return Campaign Discussion



MSR Campaign – Functional Objectives

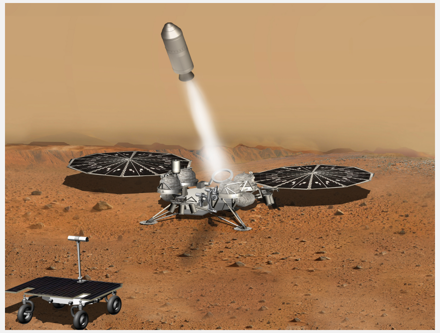
- **Acquire and return to Earth** a scientifically selected set of **Mars samples** for investigation in **terrestrial laboratories**
- Select samples based on their **geologic diversity**, **astrobiological relevance**, and **geochronologic significance**
- **Establish the field context** for each sample using ***in situ* observations**
- Ensure the **scientific integrity** of the returned samples through **contamination control** (including round-trip Earth contamination and sample-to-sample cross-contamination) and **control of environments** experienced by the samples after acquisition
- **Ensure compliance with planetary protection requirements** associated with the return of Mars samples to Earth's biosphere
- Achieve a set of **sample-related scientific objectives**
  - *Life* • *Geologic environments* • *Geochronology* • *Volatiles*
  - *Planetary-scale geology* • *Environmental hazards* • *ISRU*



MSR Campaign Architecture Elements

Sample Caching Rover (Mars 2020)

- *Sample acquisition and caching*

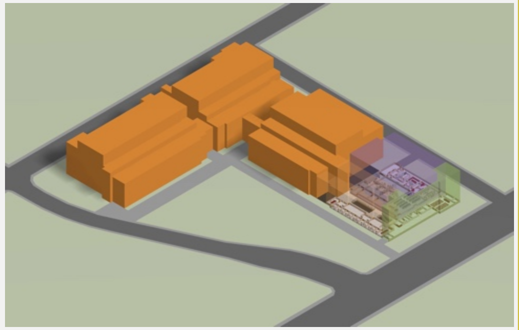


Sample Retrieval Lander

- *Fetch Rover*
- *Orbiting Sample container (OS)*
- *Mars Ascent Vehicle*

Earth Return Orbiter

- *Capture/Containment Module*
- *Earth Return Module*



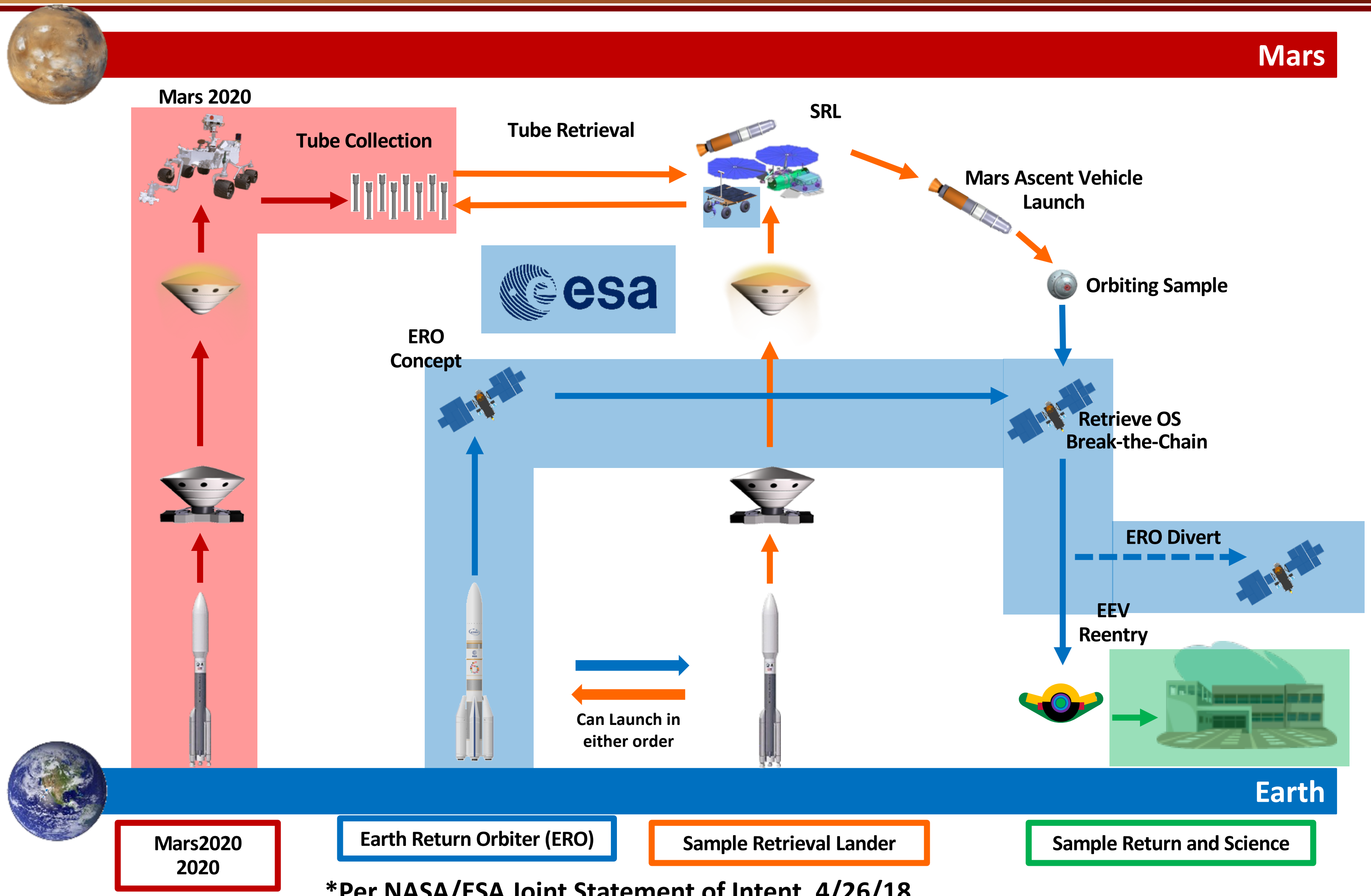
Mars Returned Sample Handling

- *Sample Receiving Facility*
- *Curation*
- *Sample science investigations*

Flight Elements

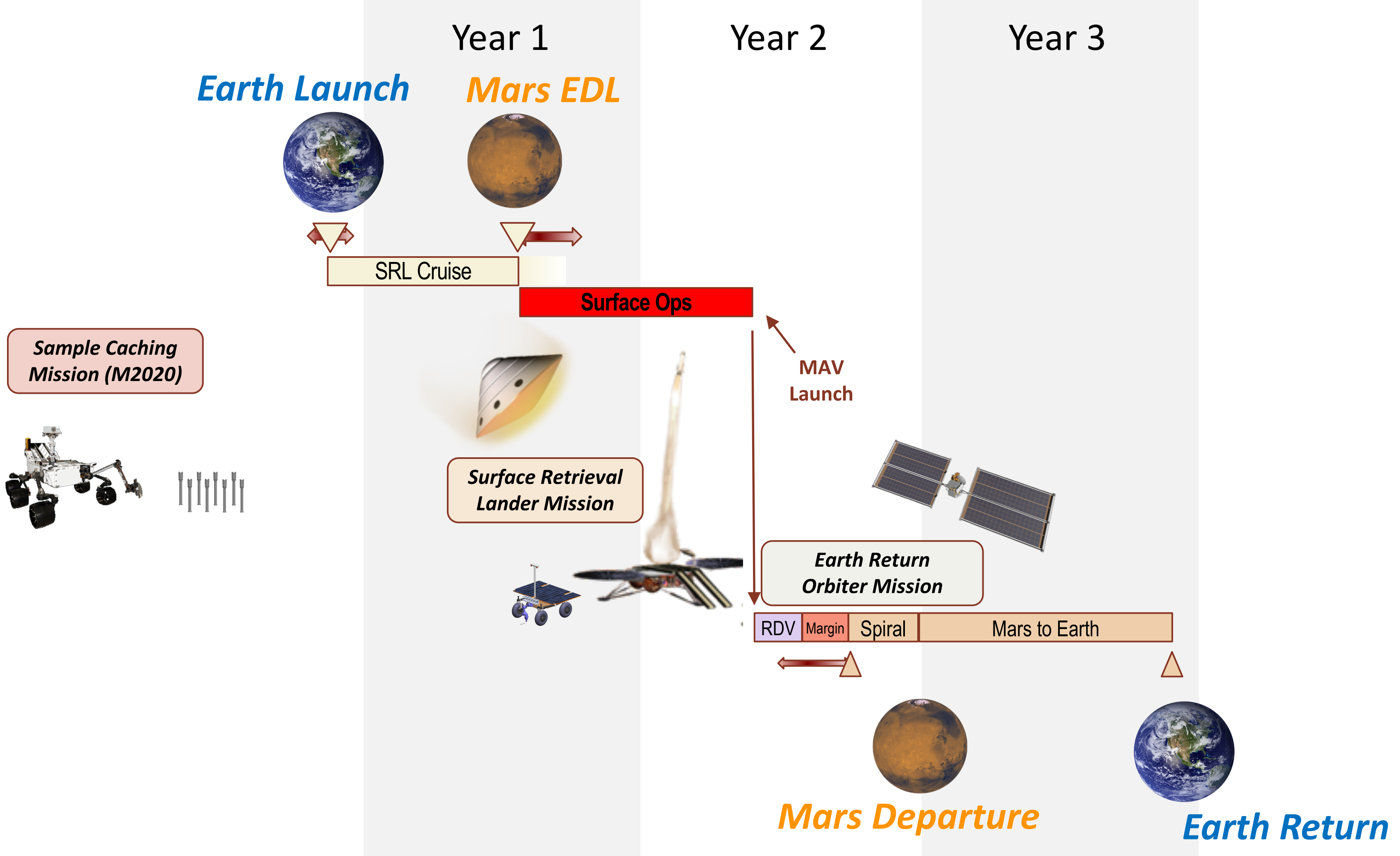
Ground Element

MSR Mission Scenario and Roles*



*Per NASA/ESA Joint Statement of Intent, 4/26/18

Notional “Fast” MSR Timeline



Fast timeline could return samples to Earth ~3 years after SRL launch

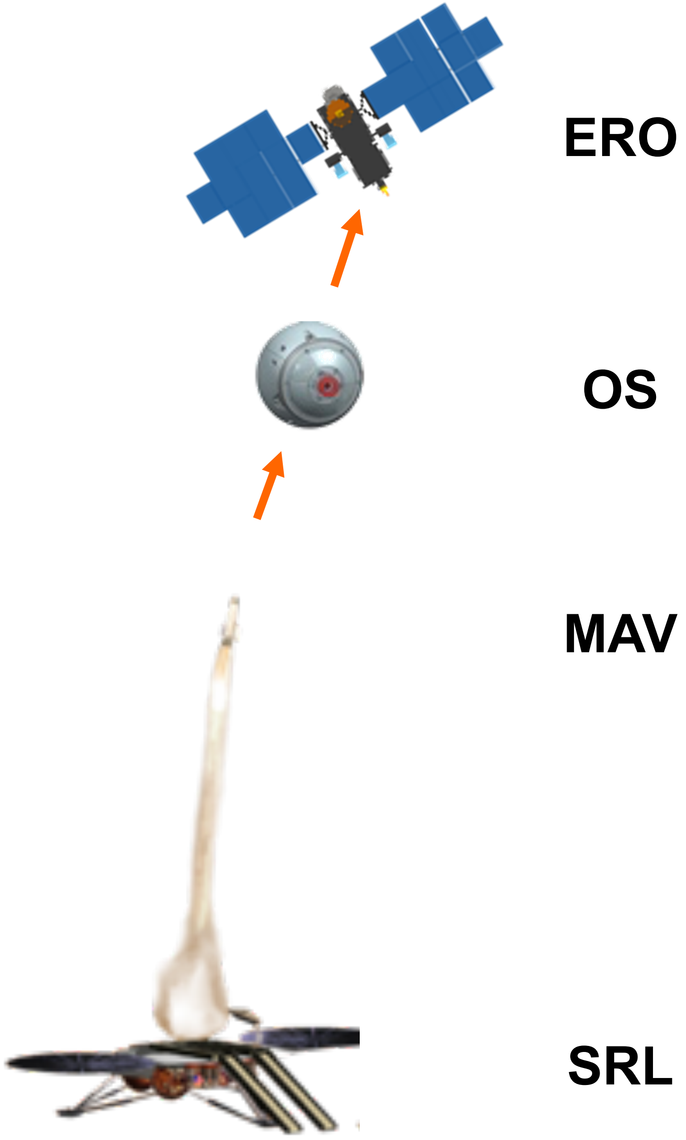
Backward Planetary Protection

- **Objective:** to prevent uncontained or unsterilized material from Mars from being released into Earth’s environment, “Break-the-Chain”
- This involves a strategy for the use of analysis, design, and testing of the elements and systems that would be implemented and validated/certified to deliver Mars surface sample tubes to Earth; while containing, immobilizing and/or sterilizing any other Mars material that might reach the biosphere of Earth.
- The key elements for BTC
  - Establishing requirements definition approach
  - National Environmental Policy Act (NEPA) process
  - Use of fault trees for element design
  - Use of various modeling tools to analyze performance and failure modes
    - Use of Quantification of Margins and Uncertainties for understanding the accuracy of our models
    - Use of Probabilistic Risk Assessment to support design studies, end-to-end reliability analysis
  - Model validation testing

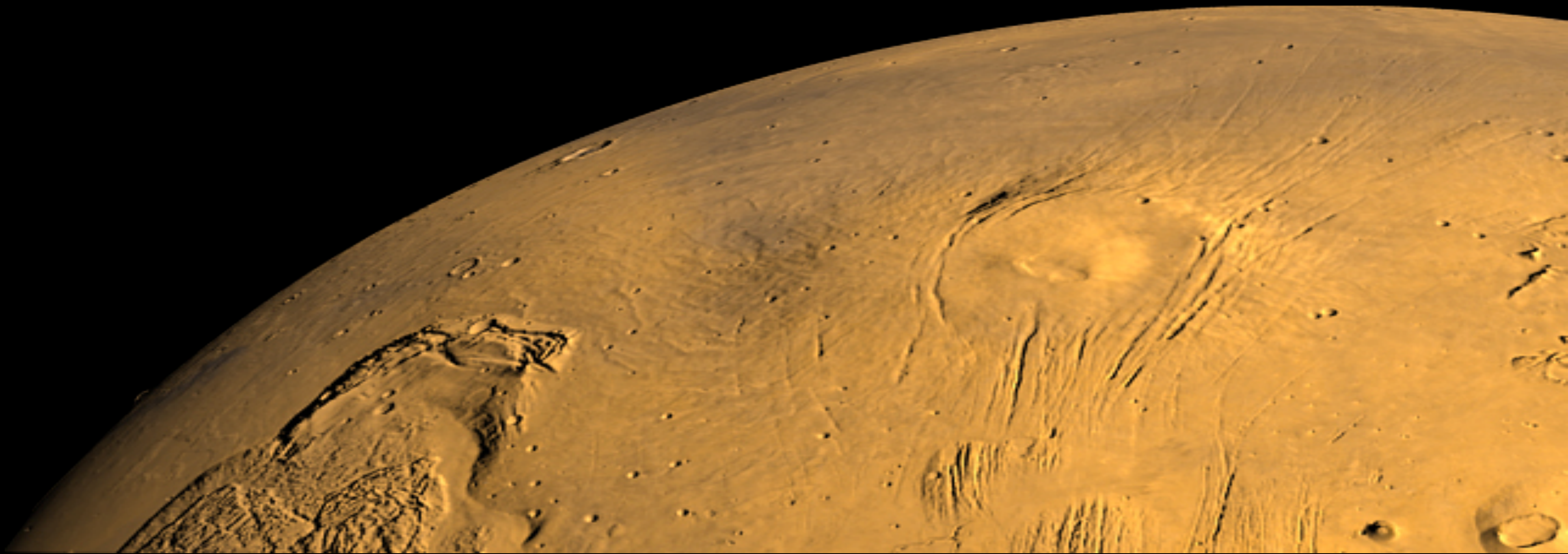
Key Trade Studies and Figures of Merit

- Figures of Merit
  - Mission success
  - Complexity
  - Cost
  - Development and operational risk
  - Performance
  - Implementation

- Architectural Drivers
  - OS design (including number of tubes and shape)
  - Approach to Break the Chain
  - MAV propulsion technology
  - SRL entry, descent and landing approach and any need augmentations
  - ERO propulsion approach and related performance

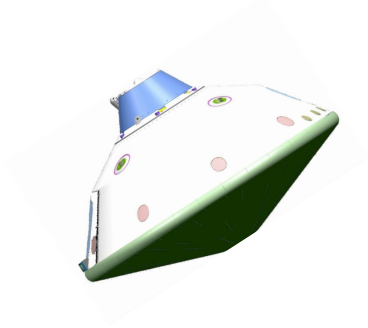


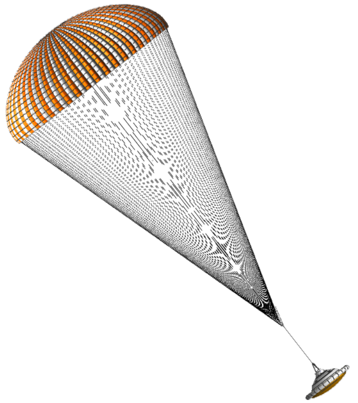
MSR Element Concepts



Lander Concept Options Under Study (1/2)

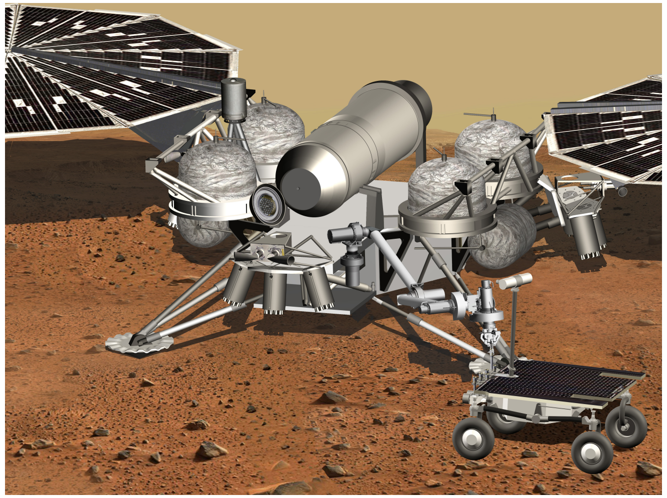
- **Mission Objectives:**
- Land on Mars
- Deploy the Sample Fetch Rover
- Maintain the lander and MAV within safe operating conditions
- Once the SFR returns with the tubes, SRL must:
  - Transfer tubes to the OS in the MPA, using the STA
  - Assemble the MPA to the MAV
  - Prepare the MAV for launch (heat and erect)
  - Launch the MAV
- Most of Entry, Descent and Landing (EDL) is common to both options and based on Mars Science Laboratory
  - Exception: 4.7m spherical heatshield



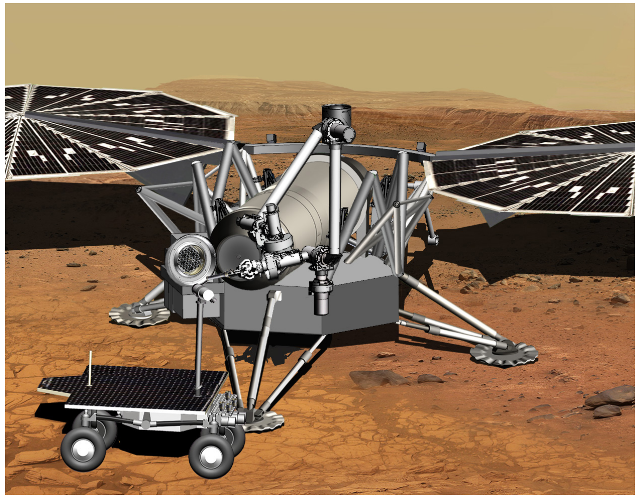


Lander Concept Options Under Study (2/2)

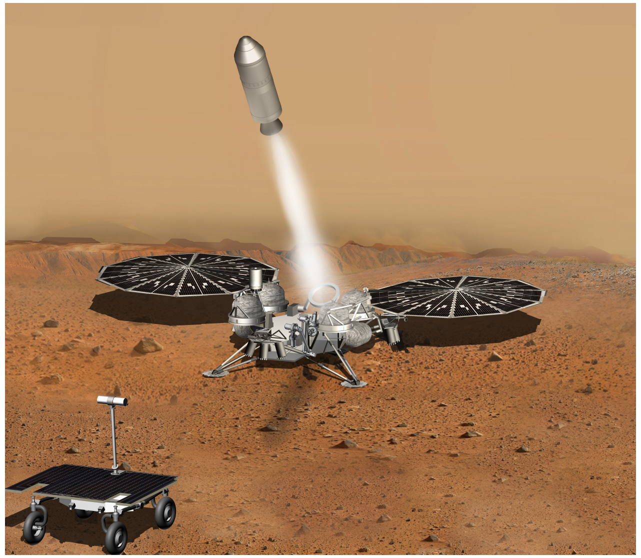
- **Key Study Elements**
  - Accommodation of MAV (400 kg) and Fetch Rover (120 kg) on lander in aeroshell, with volume and mass margins
  - Solar power and thermal design for worst case environments
  - MAV propulsion technology, performance (including mass), and reliability
  - OS: Tube accommodation, insertion into MAV
  - Planetary protection design and implementation strategies

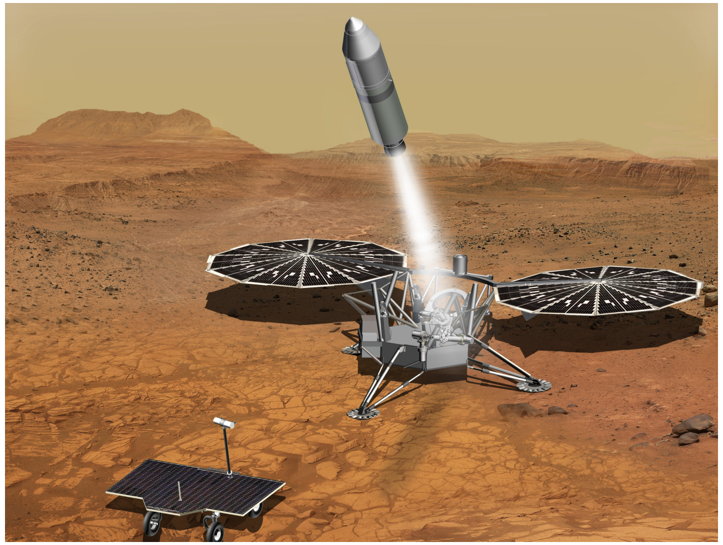


Propulsive Platform Lander



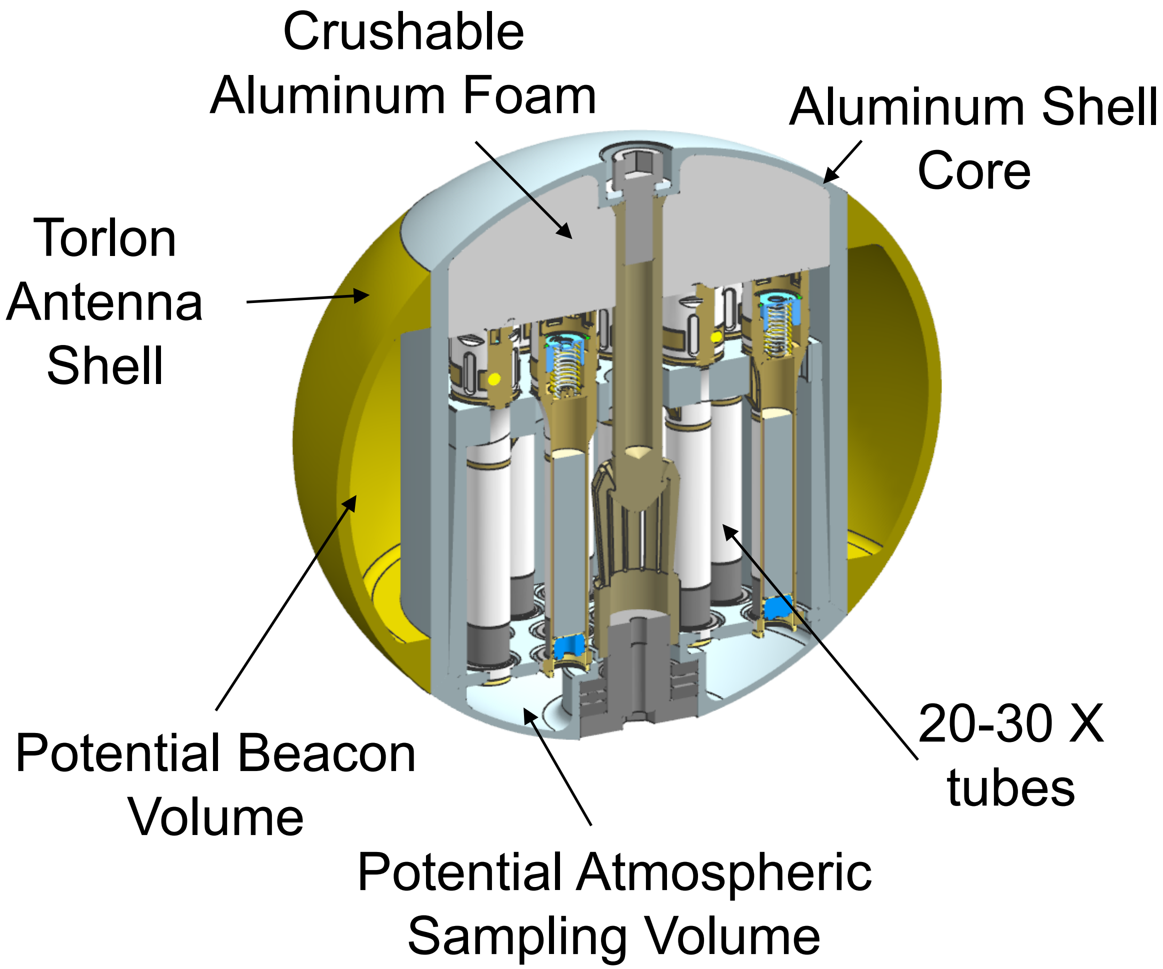
Skycrane Delivered Lander





Orbiting Sample (OS) Container Concept

- Hold desired number of samples
  - Tubes are inserted by Sample Transfer Arm on lander
  - OS then must be assembled & launched to orbit by MAV
- Hold samples securely through launch to Earth landing
- Support maintaining samples within environmental constraints
  - Sample temperature < +30 ºC
  - Keep magnetic fields < ½ mT at sample
- Accommodate rendezvous and tracking by visual wavelength cameras on orbiter
  - Sufficient albedo to be detected in Mars orbit



Mars Ascent Vehicle (MAV) Concept

Mission Objectives

- Launch from all candidate M2020 landing sites
- Inject OS into >350 km altitude orbit, > 25 deg inclination (< 1deg. dispersion)

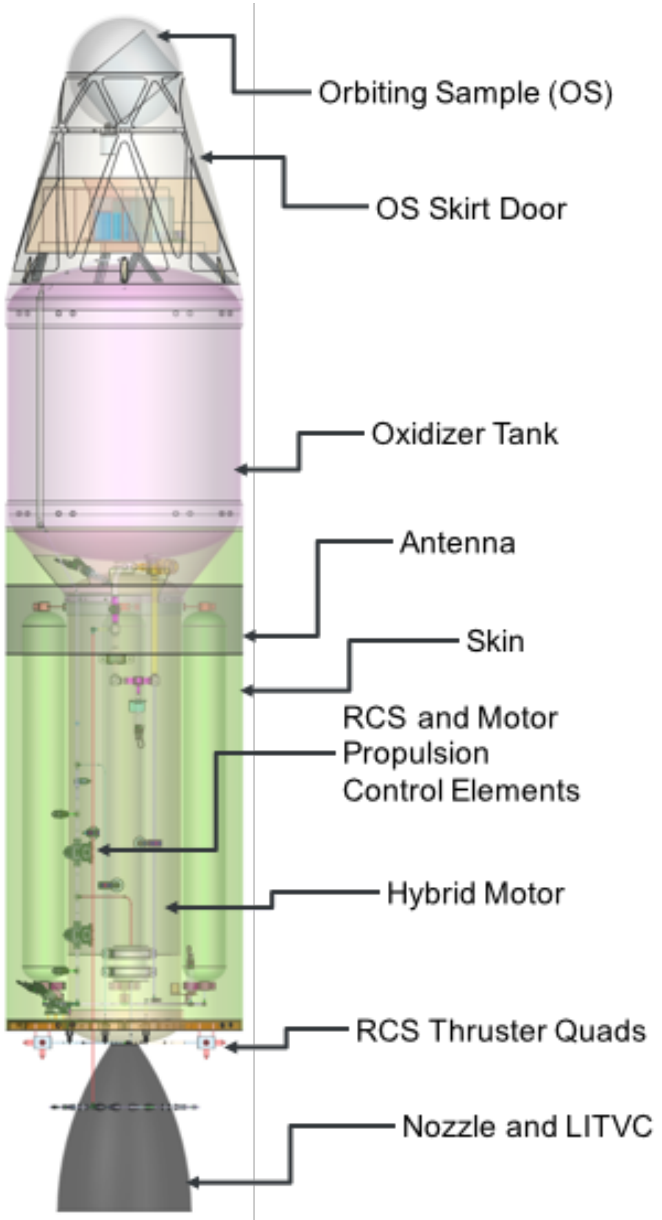
Technology Development Status

- Numerous options have been studied in the past
- Currently, two contractors are working to demonstrate performance of a single stage to orbit hybrid propulsion technology concept
  - Including ignition and stable combustion for the mission duration and a single restart
  - Both are achieving ignition with augmented combustion energy sources

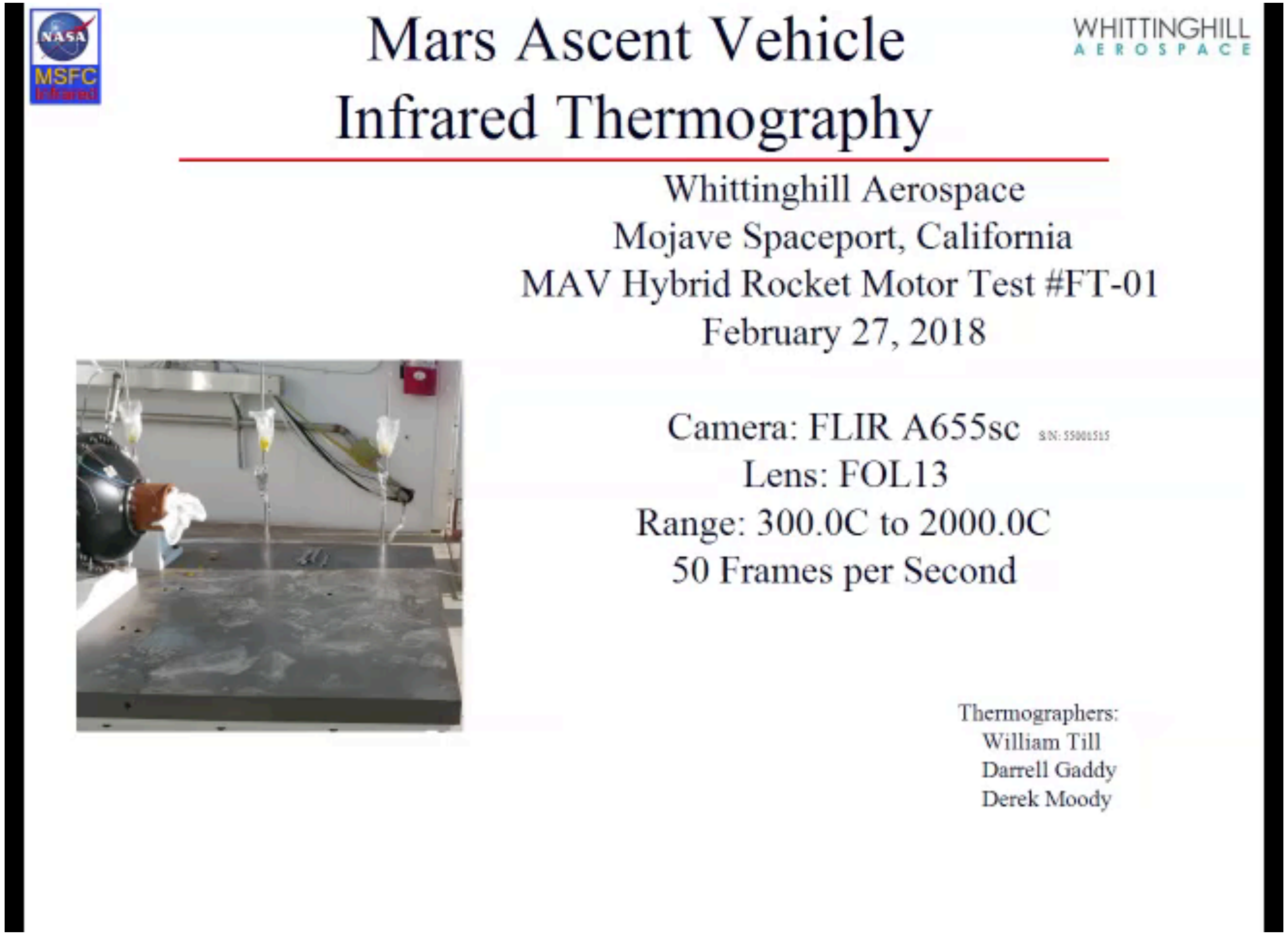
Key Trade Studies in Work

- Overall vehicle design to meet Mars mass and volume constraints
- Thrust vector control
- Design for environments

Current hybrid concept
300-400 kg Gross Liftoff Mass



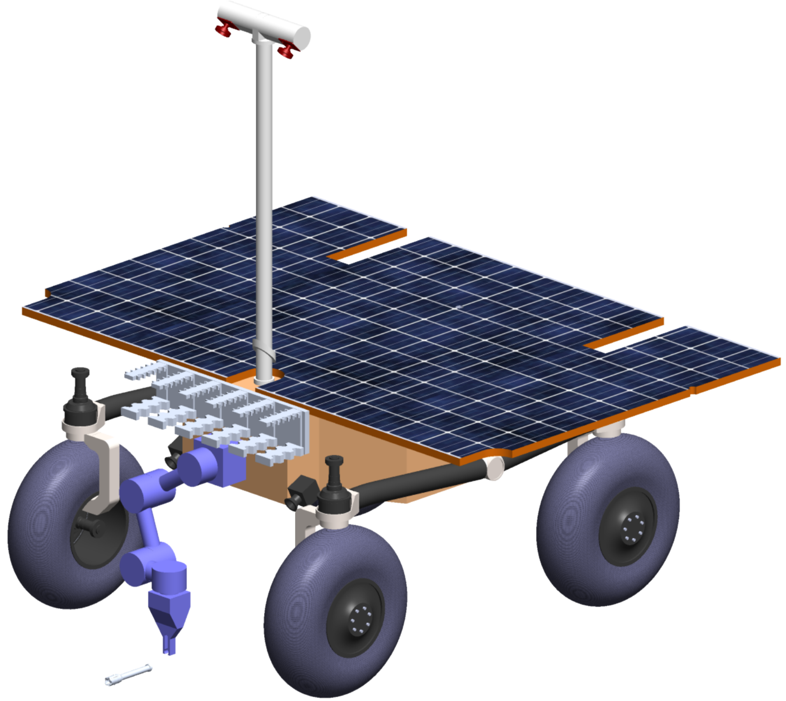
MAV – Full Scale Testing Video



Fetch Rover Concept

- **Mission Objectives**
  - Acquire sample tubes cached by M2020 and deliver them to the SRL
- **Key Specifications (based on NASA conceptual design)**
  - Rover Mass: 120 kg (Not to Exceed)
  - Egress Mass: 25 kg (Not to Exceed)
  - Stowed Volume: ~1 m^3
- **ESA Implementation**
  - Two parallel competitive contracts: Thales Alenia Space, Italy and Airbus Defence and Space, UK
  - ExoMars 2020 heritage: triple bogie, six wheel approach
  - Technology development: Mars Robotic Exploration Program (MREP) for GNC, miniaturised avionics, as well as low temperature mechanisms and batteries.

Current NASA Fetch Rover Concept



Scale is roughly 2/3 of MER

Summary

- The MSR campaign architecture trade space is well understood, with reference options defined where appropriate and options are being evaluated to achieve robust campaign architecture closure.
- The major technical elements are at an appropriately detailed level of definition for this phase of a pre-project effort.
- Technology development is proceeding per plan.
- The international and NASA cross-agency team is proceeding toward closure of a robust MSR campaign architecture in late 2019.